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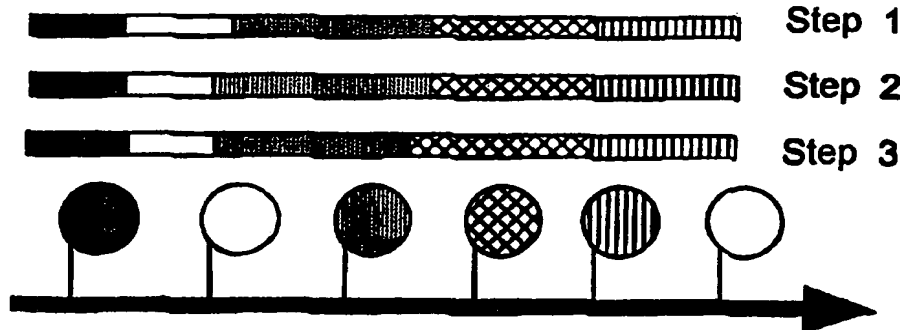
(57) Abstract

The present invention relates to a method, a controller and a system for allocating access to time slots used for transferring data between nodes in a time multiplexed network, whose bandwidth is divided into cycles which in turn are divided into control slots for control signalling and data slots for transferring data, wherein slots allocated to a primary home node may be temporarily allocated to a temporary home node, said temporary home node instead of said primary home node then temporarily having the write access to said slots, and subsequently reallocated to said primary home node. According to the invention, the degree of temporary allocation of slots to a first node is evaluated and the number of slots having said first node as primary home node is increased, based upon said evaluation and in response thereto, in order to decrease the need for temporary allocation of slots within said network.

REALLOCATION PROCEDURE

Technical Field of Invention

The present invention relates to methods, a control-
ler and a system for allocating access to time slots used
for transferring data between nodes in a time multiplexed
network, such as a Dynamic Synchronous Transfer Mode
(DTM) network, whose bandwidth is divided into cycles
which in turn are divided into control slots for control
signalling and data slots for transferring data, wherein
slots allocated to a primary home node may be temporarily
allocated to a temporary home node, said temporary home
node instead of said primary home node then temporarily
having the write access to said slots, and subsequently
reallocated to said primary home node.

Description of related art

As an example of a time multiplexed network, DTM is
a broadband network architecture (see e.g., Christer
Bohm, Per Lindgren, Lars Ramfelt, and Peter Sjödin, The
DTM Gigabit Network, Journal of High Speed Networks,
3(2), pp 109-126, 1994 and Lars Gauffin, Lars Håkansson,
and Björn Pehrson, Multi-gigabit networking based on DTM,
Computer Networks and ISDN Systems, 24(2), pp 119-139,
April 1992). DTM is a circuit switched network and inten-
ded to be used in public networks as well as in local
area networks (LAN's). It uses channels as the communica-
tion abstraction. The channels differ from telephony
circuits in various ways. First, establishment delay is
short so that resources can be allocated/reallocated
dynamically as fast as user requirements change. Second,
they are simplex and so minimise overhead when the com-
munication is unidirectional. Third, they offer multiple
bit-rates to support large variations in user capacity
requirements. Finally, they are multicast, allowing
several destinations.

DTM channels share many beneficial properties with circuits. There is no transfer of control information after channel establishment, resulting in very high utilisation of network resources for large data trans-
5   fers. Support of real-time traffic is natural; there is no need for policing, congestion control or flow-control within the network. The control information is separated from data, which makes multicast less complex. The transmission delay is negligible (i.e., less than 125 ms) and
10   there is no potential for data loss because of buffer overflow as in ATM (Asynchronous Transfer Mode). Bit-error rates depend on the underlying link technologies, and switches are simple and fast due to strict reservation of resources at channel set-up. DTM can show good
15   performance in areas where traditional circuit-switched networks fall short: dynamic bandwidth allocation, channel establishment delay, and as shared media networks.

The basic topology of a DTM network is preferably a
20   bus with two unidirectional optical fibers connecting all nodes, but can also be realised by any other kind of structure, e.g., a ring structure. The DTM medium access protocol is a time-division multiplexing scheme. The bandwidth of the bus is divided into 125 µs cycles, which
25   in turn are divided into 64-bit time slots. The number of slots in a cycle thus depends on the network's bit-rate. The slots are divided into two groups, control slots and data slots. Control slots are generally static and used to carry messages for the network's internal operation.
30   The data slots are used to transfer user data between the nodes.

Generally, in each network node there is a node controller, which controls the access to data slots and performs network management operations.
35   Control slots are used exclusively for control messages between these node controllers. Each node controller preferably has write access to at least one control

slot in each cycle, which it uses to multicast control
messages to other node controllers. Here, multicast
refers to sending information to one or more downstream
nodes on a bus, as the transmission medium is unidirec-
5   tional. Since write access to control slots is exclusive,
the node controller always has access to its control
slots regardless of other nodes and network load.

The majority of the slots in a cycle are data slots.
Access to data slots changes over time, according to
10   traffic demands. Write access to slots is controlled by
slot access, sometimes referred to as slot tocens. A node
controller may write data into a specific slot only if
the node has write access to this specific slot. The slot
access protocol, or token protocol, guarantees the slot
15   access to be conflict free, which means that several
nodes do not write data into the same slot.

One optimisation in slot access management is to
introduce so called block access or block tokens, i.e.
access to a number of slots arranged contiguously in a
20   slot range. A block token, i.e. access to a group of
slots, may be transferred in a single control message,
but can only be used for particular combinations of
slots. For instance, block access may be denoted by a
slot number and an offset giving the number of contiguous
25   slots in the group or block.

Also, write access to slots (single or block) may be
exchanged or varied between different nodes during net-
work operation, for example as a result of a node asking
for more transferring capacity by requesting write access
30   to more slots from other nodes. One of the major problems
with this kind of write access allocation is fragmenta-
tion. The average number of contiguous available time
slots allocated to a node of a DTM-like network is small
due to the random movement and exchange of slot access
35   and the varying capacity of users' requests. This gives
relatively long access delays (in the millisecond region)

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for high capacity channels, particularly at moderate to
high load.

One way of dealing with this fragmentation problem
is to define a home node for each slot at network start-
up or during network operation. This is preferably done
in such a way that slots having the same home node
preferably define at least partly a continuous slot
range. The nodes may then "borrow" available or free
slots from each other, sending back free slots to their
respective home node, for example when a significant time
has passed. Also, two or more consecutive slots are
preferably merged into a single block token when existing
in the free pool of a node.

Hence, in a DTM-like system of this kind, a first
node may have write access to a first set of slots and a
second node may have write access to a second set of
slots. Then, the first node is said to be the primary
home node of the first set of slots and the second node
is said to be the primary home node for the second set of
slots. However, if the first node at some time require
more transferring capacity to fulfil the demands of one
or more users attached to the first node, it may tempora-
rily lend or borrow slots from another node, for example
the second node, presently having a surplus of slots. In
such a case, one or more slots having the second node as
primary home node may be temporarily allocated to the
first node, the first node then being a so called
temporary home node of said one or more borrowed slots
and hence temporarily having the write access thereto.
When the demand for transferring capacity in the first
node decreases, or for example after a predefined time
interval or, said one or more borrowed slots are returned
to their primary or actual home node, i.e. the second
node.

However, nodes in, e.g., an integrated services net-
work will have different load depending on the equipment
attached to it. Also, the load will vary in time. In case

of non-uniform traffic, a node that requires high capa-
city may have to regularly borrow slots from and return
slots to their respective home node, which results in
overhead for slot negotiation and longer set-up times for
5   the channels.

Summary of the invention.
        The object of the invention is to avoid the problems
mentioned above with overhead for slot access negotiation
10   in a time multiplexed network, such as a Dynamic Synchro-
nous Transfer Mode (DTM) network, whose bandwidth is
divided into cycles, which in turn are divided into time
slots comprising control slots for control signalling and
data slots for transferring data.
15   According to the invention, this and other objects
are achieved by a method, a controller and a system
having the features presented in the accompanying claims.
        Hence, according to one aspect, the invention is
preferably provided in a network wherein slots allocated
20   to a primary home node may be temporarily allocated to a
temporary home node, said temporary home node instead of
said primary home node then temporarily having the write
access to said slots, and subsequently reallocated to
said primary home node.
25   According to the invention, the degree of temporary
allocation of slots to a first node is evaluated and,
based upon this evaluation, the number of slots having
said first node as primary home node is increased in
response thereto in order to decrease the need for tempo-
30   rary allocation of slots within said network.
        Preferably, the transfer of slot ownership is
initiated by a request from the node having a lack of
slot capacity. Such a request, or any other type of
reallocation initiation, may for example be provided when
35   the node has borrowed slots a predifined number of times,
when the ratio between the number of slots having the
node as temporary home node and the number of slots

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having the node as primary home node exceeds a predefined
value, when the allocation or "loan" has to be directed
over a substantial distance over the network. As another
alternative, a predefined fraction or a predefined number
5   of slots may be arranged to change owner, i.e. primary
home node, each time one node borrows slots from another
as a result of the loan itself.

         Hence, according to the invention slots may be
reallocated to new home nodes during network operation.
10   In one embodiment, a first node sends a request to a
second node to get more slots assigned to it as primary
home node and the second node transfers slots to the
first node so that the slot capacity assigned to the
first node as primary home node is increased and the slot
15   capacity assigned to the second node as primary home node
is decreased. Preferably, the allocation is done in such
a way that the tokens that will share the same primary
home node will define at least partly a continuous slot
range.

20   Preferably, slots having the same primary home node
define a continuous slot range. Then, all nodes assigned
as primary home nodes for slots located, in a cycle, in-
between slots having a first node as primary home node
and slots having a second node as primary home node may
25   transfer slot write access in the following way.

         The second node is assigned as present node. Write
access to a number of slots, amounting to the number
requested by the first node, having the present node as
primary home node and neighbouring a slot range having a
30   next node as primary home node are reallocated from the
present node to the next node, said slot range of the
next node either being the slot range of the first node
or being a slot range of a node located in between the
slot ranges of the first and the second nodes. The
35   distance between the slot range of the next node and the
slot range of the first node is preferably smaller than
the distance between the slot range of the present node

and the slot range of the first node. In case of the next
node not being the first node, the next node is assigned
as the present node and the step of reallocating is
repeated. This procedure is referred to as a "push",
5   since write access to the requested number of slots is
pushed from the second node to a next node to another
next node and so on, until it has been pushed to the
first node.

According to the invention, the problems mentioned
10 above are avoided by efficiently reallocating slot access
to new primary home nodes, so minimising overhead for
slot access negotiation. The criteria for when a node
should request more slots assigned to it as primary home
node, which node it should ask and how much capacity it
15 should request, can be chosen in various ways, as mentio-
ned above and below. However, resilience has to be imple-
mented in order to avoid oscillation and thus overhead
for control signalling.

Preferably, but not necessarily, each node has a
20 node controller, which controls the write access to slots
and in which a home node is defined for each slot and
free slots may be sent back to their respective home
nodes when a significant time has passed.

An advantage of the invention is that it is a simple
25 and easily implemented mechanism, which strongly improves
the performance of the network. The probability of that a
node has to temporarily borrow slots from another node is
decreased.

A further advantage of the invention is that low
30 fragmentation is maintained.

Yet another advantage is that the reallocation of a
slot to a new home node may be realised even though the
slot is in use, e.g., by another node temporarily having
access to the node, i.e. being the temporary home node of
35 said slot.

Still another advantage of the invention is that it, especially in combination with a slot reuse method, may further improve the bandwidth utilisation.

5 Brief description of the drawings

Exemplifying embodiments of the invention will be described in greater detail below with reference to appended drawings, in which:

Fig 1 shows a dual-bus DTM network;

10 Fig 2 shows a DTM 125 μs cycle that is divided into data slots and control slots;

Fig 3 shows different block slot access or block tokens in a slot-segment map;

Fig 4 shows how new home nodes are defined for slots

15 in consecutive steps according to the invention; and

Fig 5-8 show results from simulations where the ownership reallocation and push mechanisms are included.

Detailed description of preferred embodiments

20 First, as an example of a time multiplexed network, the DTM MAC (Medium Access Control) protocol will be described with reference to Fig 1 and 2. The basic topology of a DTM-like network is a bus with two unidirectional optical fibers connecting all nodes Node 0, Node 1,

25 ..., Node N-1, as shown in Fig 1. Several buses with different speeds may be connected to form an arbitrary multistage network. In the current prototype implementation, buses can be combined into a two-dimensional mesh. A node at the junction of two buses can synchronously

30 switch data slots between the two buses. This allows for efficient switching with constant delay through the node. The primary communication abstraction in DTM is a multi-rate, multicast channel.

A DTM medium access protocol is a time-division

35 multiplexing scheme. The bandwidth of the bus is divided into 125 μs cycles, which in turn are divided into 64-bit time slots (or slots for short) as illustrated in Fig 2.

The number of slots in a cycle thus depends on the net-
work's bit-rate; for instance, on a 6.4 Gbit/s network
there are approximately 12500 slots per cycle.

As shown in Fig 2, the slots are further divided
5   into two groups, control slots and data slots. Control
slots are used to carry messages for the network's inter-
nal operation, such as messages for channel establishment
and bandwidth reallocation. The data slots are used to
transfer user data and are not necessarily read by
10   intermediate network nodes, i.e. nodes arranged between
the source node and the destination node or nodes.

Generally, but not necessarily, in each network node
there is a node controller NC, which controls the access
to data slots and performs network management operations,
15   such as network start-up and error recovery. The main
tasks of the node controller NC are to create and termi-
nate channels on demand from users and to manage network
resources in response to user requests and in the back-
ground.

20   Control slots are used exclusively for messages
between node controllers NC. Each node controller NC
preferably has write permission to at least one control
slot in each cycle, which it uses to broadcast control
messages downstream to other nodes. Since write access to
25   control slots is exclusive, the node controller NC has
always access to its control slots regardless of other
nodes and network load. The number of control slots a
node uses may vary during network operation.

The network is not restricted to a dual-bus, as
30   exemplified in Fig 2, but can be realised by other kind
of structures, e.g., a ring structure with an arbitrary
number of nodes. The transmission media can besides to
optical fibers be coaxial cables or any other high band-
width transmission media. The bandwidth of the DTM dual
35   bus in the preferred embodiment is divided into 125 μs
cycles, which in turn are divided into 64-bit time slots.
The invention is of course not restricted to time

multiplexed networks with these values, but can be used
in networks with cycles and slots of arbitrary sizes.

Principles for resource management (called slot
access of token management) will be described below. The
majority of the slots in a cycle are data slots. Access
to data slots changes over time, according to traffic
demands. Write access to slots is controlled by so called
slot access. A node controller NC may write data into a
slot only if the node has write access thereto. The token
or write access protocol guarantees the slot access to be
conflict free, which means that several nodes do not
write data into the same slot. The write access to slots
are controlled by the node controllers and it may be
transferred from a node controller to another via control
messages. In the following the write access protocol may
also be refereed to as the token protocol.

Control messages for channel establishment and
bandwidth reallocation contains set of slots or tokens as
parameters. However, a control message is 64 bits and can
therefore have only a small number of parameters. This
means that if a user requests a large bandwidth transfer,
it may be necessary to send several control messages to
create the channel. This introduces extra access delay
and consumes control signalling capacity.

Several mechanisms to decrease the amount of infor-
mation that needs to be sent during channel creation and
slot reallocation are considered. The first optimisation
in token management is to introduce so called block
tokens or slot range access. Access to a slot range may
be transferred in a single control message and represents
access to a group of slots, i.e. a group of slot tokens,
but can only be used for particular combinations of slot
access. For instance, block token may be denoted by a
slot number and an offset giving the number of contiguous
slots in the group or block.

In a basic form, the slot access protocol guarantees
that a data slot can never be used by two nodes simulta-

neously on the bus, which sometimes may be too conserva-
tive. Nodes are connected by bus segments. Channels
typically use a subset of the segments on the bus, and
the rest are reserved but left unused and thus wasting
5   shared resources. A better alternative is to let channels
only reserve capacity on the segments between the sender
node and the receiver node or nodes, as exemplified in
Fig 3. A single slot may in this case be used multiple
times on the bus. For example, channel D and E are using
10   the same slots as channel A and C but on different
segments. This is referred to as slot reuse. Slot reuse
enables simultaneous transmissions in the same slot over
disjointed segments of the bus. To allow slot reuse in a
DTM-like network, the slot access format is extended to
15   include parameters describing the segment(s) it is repre-
senting. The slot access management protocol is also
modified to avoid conflicts in the slot number dimension
as well as in the segment dimension.

A distributed slot access manager will be described
20   in the following. Each node regularly broadcasts status
information about how many free slots or slot ranges it
has and how large they are. The other nodes store this
information in their status tables. A node that wants
more capacity consults its status table to decide from
25   which node to request slots. The broadcast state informa-
tion gives an approximate and dated view of the current
state of slot information, so slot requests may be rejec-
ted because they were sent to nodes that no longer have
free slots to give away.

30   The protocol on the initiating side may for example
work as follows when a user request arrives to a node:

1. If the node has sufficiently many free slots to
satisfy the request, it allocates the requested amount of
slots to the user, and starts the channel by sending a
35   channel establishment message to the destination node and
then transmitting data using the reserved slots.

2. Otherwise the node marks its available slots as
being reserved, and then preferably, but not necessarily,
checks its status table: if the total amount of free
slots in the network is not enough to fulfil the request,
5   then the request is rejected (blocked). Otherwise the
node requests slots from nodes with unused capacity.

3. If one of these nodes receiving a slot request
does not have the requested amount of free slots, it may
still gives away all the slots it has. In any case, it
10   sends a response back to the requesting node. A node
preferably, but not necessarily, fulfils incoming
requests in strict first-in-first-out order.

4. When a node receives a response to a slot
request, it marks the slots it receives in the response
15   (if any) as being reserved. When the node has received
responses to all requests it has sent, it either starts
the channels or rejects the user request, depending on
whether or not it has acquired sufficient capacity. If
the user request is rejected, the reserved slots are
20   marked as free again.

At start-up all free slots may be evenly distributed
among the network nodes, and each node may preferably
then take at least one of its free tokens, move it (them)
to the active state and declares it (them) to be a
25   control slot. User requests may then be accepted and slot
access can be moved between nodes on demand.

The pool of free slots may be distributed in other
ways than evenly, e.g., proportionally (nodes upstream
get more slots than nodes downstream) among all nodes.

30   In the general case, the average number of contigu-
ous free slots in a node is small due to the random move-
ment of slots and the varying capacity of users' requ-
ests. This fragmentation renders the block token optimi-
sation practically useless, and the access delay is rela-
35   tively long (milliseconds) for high capacity channels. To
make block allocation efficient, it is necessary to
reduce fragmentation of free slots or slot ranges, other-

wise fragmentation will be by far the main contributor to access delay for high bandwidth channels at moderate to high load. Low capacity channels will usually have a very short channel establishment delay independent of the

5   current amount of fragmentation.

In the case of slot reuse, the fragmentation problem is even worse, as fragmentation may occur in both slot (time) and segment (space) dimensions (see Fig 3). In the distributed slot access manager system, most of the frag-

10   mentation is a result of using many free pools (one for each node). Two free adjacent tokens, i.e. slots or slot ranges, can only merge if they are found in the same node.

An example of a distributed scheme that tries to

15   avoid fragmentation if possible and increases the average block size of free slots belonging to a node works as follows:

1. A home node is defined for each slot or slot range at network start-up, and the slots are distributed

20   in such a way so slots having the same primary home node will always define at least partly a continuous slot range. This results in a large average slot access area or token area in the token map shown in Fig 3.

2. When two consecutive slots or slot ranges having

25   the same slot or segment range exist in the free pool, they are merged into a single token, i.e. a single slot range access (sometimes a recursive split and merge operation is needed). When performing a merge, a segment merge is prioritised before a slot number merge. (The

30   reason for this is that slot access spanning over just a few segments are less useful to other nodes than slot access spanning over many segments.) Two segment-consecutive slots representing at least partly the same slot range and existing in the free pool of a node are split

35   to obtain segment-consecutive slot access, representing the same slot range, which are merged into a single token.

3. When a node gets a slot access request from the local user or a remote user, slots is picked from the free slot pool, preferably, but not necessarily, using a best-fit algorithm in slot number and segment number dimension (see Fig 3). The "value of a token" is calculated as the area of a token in the token map and the token with the smallest area that fulfil the requested capacity is picked. A cost function can also be defined as a function of, e.g., number of slots, number of segments, location of slots and location of segments, which function should be minimised, however, still fulfilling the requested capacity.

4. When a node needs to request slots from other nodes, it does not ask for small chunks from several nodes if it is possible to ask for larger chunks from fewer nodes. The status tables provide this information. Transfer of slot access is therefore more efficient, and there are fewer establishment messages and less fragmentation.

5. Free slots are sent back to primary home nodes when they have been idle for a significant time or after a long transfer or after having been used a certain number of times or the like.

This scheme returns slots to their respective primary home nodes as a way to increase the probability that two consecutive slot or slot ranges can be merged in the free list, which decreases fragmentation. If the slots are returned to their respective primary home nodes too soon, i.e., if the home node "gravity" is too strong, the scheme will result in less sharing of resources and unnecessary control signalling. If it is too weak, fragmentation will still remain a problem. The "gravity" may be changed during the operation of the bus.

However, nodes in, e.g., an integrated services network will have different load depending on the equipment attached to it. Also, the load will vary in time. In case of non-uniform traffic, a node that requires high capaci-

ty may have to regularly return slots to their respective
home nodes, which results in overhead for slot access
negotiation and longer set-up times for the channels.

To avoid this, a new mechanism which defines new
5   home nodes for slots during network operation, is
introduced:

According to an exemplifying embodiment of the
invention, a first node sends a request to a second node
to get more slots assigned to it as primary home node and
10   the second node transfers slots to the first node as new
primary home node so that the slot capacity assigned to
the first node as primary home node is increased and the
slot capacity assigned to the second node as primary home
node is decreased. Preferably this is done in such a way
15   that the slots that will have the same primary home node
will define at least partly a continuous slot range.

The invention avoids the problems with overhead for
slot access negotiation by efficiently reallocate slots
to new home nodes. Using the invention, low fragmentation
20   is maintained. It is desirable to be able to define new
primary home nodes for slots even though they are in use,
i.e. even though they are currently allocated to some
other node as temporary home node.

Preferably, slots sharing the same primary home node
25   define a continuous slot range. Then, all nodes assigned
as primary home nodes to slots located, in a cycle, in-
between slots having the first node as home node and
slots having the second node as home node may for example
transfer slot access in the following way:
30   1. The second node is assigned as present node.
         2. Access to a number of slots, amounting to the
number requested by the first node, having the present
node as home node and neighbouring a slot range having a
next node as home node are reallocated from the present
35   node to the next node, said slot range of the next node
either being the slot range of the first node or being a
slot range of a node located in between the slot ranges

of the first and the second nodes and the distance
between the slot range of the next node and the slot
range of the first node preferably being smaller than the
distance between the slot range of the present node and
5   the slot range of the first node.

3. In case of the next node not being the first
node, the next node is assigned as the present node and
the step 2 of reallocating is repeated.

This procedure is referred to as push.

10   To explain this procedure in detail, an example is
given with reference to Fig 4. Suppose there are six
nodes connected to a bus as shown in Fig 4. To each node
is assigned a set of consecutive slots in such a way that
the first slot range within the cycle is assigned to node

15   1 as home node, the second slot range within the cycle is
assigned to node 2 as home and so on, as indicated in
Step 1 of Fig 4.

Suppose now that node 4 has determined or evaluated
that it often requests or borrows many slots and thus

20   permanently needs more. It then requests, e.g., node 2 to
transfer a number of slots in a slot range. The node to
be requested can be chosen in several ways, as will be
discussed below.

Node 2 now chooses a portion of its slots, which

25   corresponds to a set of consecutive slots closest to the
slot range assigned to node 3 as home node, and transfers
it to node 3. Consequently, node 3 increases the size of
the slot range assigned to it as home node, as shown in
Step 2 of Fig 4.

30   Node 3 repeats this procedure and thus transfers a
portion of its slot range, which is of the same size as
the one received but corresponds to consecutive slots
closest to the slot range assigned to node 4 as home
node, to node 4. Now, the size of the slot range assigned

35   to node 4 as home is increased, as indicated in Step 3 of
Fig 4.

This method avoids fragmentation of the slot pools, since consecutive slots will be assigned to each node as home. Slot range access, or block tokens, which shall change home node, are in this manner "pushed" through the

5   nodes between the two negotiating nodes (Step 1-3), thereof the name of the procedure.

With this configuration (node 1 is assigned as home to the first slot range, node 2 is assigned as home to the second slot range etc.) it is possible to implement a

10   simple procedure for sending free slots, which may have been in use during the reallocation, to their respective new home nodes.

After the allocation, each home node has information about the slots assigned to it as home node. According to

15   the simple procedure for sending free slots to their respective new home nodes, the node that uses the slot or slot range sends it back from where it got it when it does not need it any more. This because the node may not know the new home node after the reallocation. The node

20   that receives the slot checks if the slot still is assigned to it as home node. If not, the node checks whether the slot or slot range corresponds to slot number(s) lower or higher than the slots corresponding to the slot range now assigned to it as home. If it corre-

25   sponds to lower slot number(s), the slot or slot range access is sent to the node's closest neighbour with node number lower than its own, and if it corresponds to higher slot number(s), the slot or slot range access is sent to the node's closest neighbour with node number

30   higher than its own. The next node that receives the slot or slot range access repeats the procedure until the slots are returned to its new home node. In this way, also returning slots are pushed through the nodes from the old home node to the new home node.

35   Using this simple procedure, the change of home node does not affect the use of the slots at that time. Since control messages are multicast in for example DTM, the

intermediate nodes can observe when nodes borrow slots. In this way the push procedure may be implemented in such a way that the intermediate nodes automatically perform the reallocations of new home nodes.

5   Which point in time a node should request more slots assigned to it as home may be decided every time the node requests or borrows slots from other nodes. To avoid oscillation, resilience has to be included, e.g., by requesting a home node change only every n'th time a node

10   requests or borrows slots from other nodes or for example by only reallocating a certain part of the slots borrwed. Another technique that may be used is to correlate the node's borrowed slots to its owned. If, e.g., the quotient of borrowed slots, i.e. slots having the node as

15   temporary home node, and owned slots, i.e. slots having the node as primary home node, exceeds a predetermined value, a home node reallocation is initiated.

       From which node a home node movement shall be requested may be determined for example by using one or more

20   of the following methods.

       In the first method, the node requests the node which at the time has most free slots (capacity). This is easily found by referring to its status table, where information about the free capacity in each node is

25   stored.

       In the second method, the node maintains a record of nodes from which it has borrowed slots, e.g., most recently or during a predetermined period. It then requests a change of home node from the node it has,

30   according to the record, borrowed most slot capacity from.

       How many slots or how large slot range a node should request to be assigned to it as home may be chosen as a fraction of the slot capacity the node requests or

35   borrows from other nodes. It may be implemented as the value at the time for reallocation or as a mean value by referring to the record of loans. Alternatively, the

quotient of borrowed slots and owned slots may be used.
It may also be set as a fixed amount of slots or may be
controlled by management operations.

In some situations, the procedures may be utilised
5   more efficiently on the DTM bus when combined with a slot
reuse method as to be described in the following. When
the first node sends a request to the second node to get
more slots assigned to it as home node, it requests slot
access corresponding only to predetermined segments of
10   the network. The second node transfers slot access
corresponding only to these segments to the first node,
letting slot access, which correspond to the same slots
but on different segments, be unchanged. This increases
fragmentation, but will in some situations be advanta-
15   geous.

Results from simulations performed, with the owner-
ship reallocation and push mechanisms included, will be
described in the following. In the simulations, realloca-
tion of resources in the background to adapt to non-
20   uniform traffic, is evaluated. The frame size is chosen
to be 2400 slots, which corresponds to a communication
link capacity of approximately 1.2 Gbit/s. For lower
communication link capacity less processing and control
signal capacity for each node are required. Thus, it is
25   possible to simulate smaller transfers without trashing
phenomena, i.e., very low throughput at high offered
loads due to lack of signal capacity. Small transfers are
used to more clearly observe the difference when inclu-
ding the push mechanism. The traffic in each node is
30   exponentially distributed and a few nodes are designed as
hot-spots, i.e., they have much more traffic in the
simulations.

Initially, the home node assignment is evenly dis-
tributed among the nodes as can be seen in Fig 5. The
35   change of home node is executed when a node has received
a number of requests for more capacity from another node.
Then it "pushes" write access to one slot through the

intermediate nodes to the requesting node. In the simula-
tions this is done for every 10'th request, which intro-
duces inertia in the system. This is important since the
push mechanism and ownership reallocation mechanism shall
5   cope with long term variations in load. The state at
approximately 100 ms is shown in Fig 6. During the opera-
tion of the network, the home node is changed according
to the load, i.e., the hot-spots will have more slots
assigned to them as home.

10   The ownership allocation mechanism will reduce the
amount of reallocations of slots for, e.g., client/server
like traffic. In Fig 7 is shown the throughput and in Fig
8 the channel set-up time as a function of offered load
with and without the ownership allocation and push

15   mechanisms. Results are presented for transfers of 4 kB
and 8 kB. It can be observed that the throughput is
significantly higher with the ownership allocation and
push mechanisms. Also, the channel set-up time is lower.
This is the case since the hot-spots do not need to

20   return slots to other nodes as frequently as with an
evenly distributed home node assignment.

         According to the invention, there is provided
efficient reallocation of slot access to new home nodes,
so minimising overhead for slot access negotiation. The

25   criteria for when a node should request more slots
assigned to it as home node, which node it should ask and
how much capacity it should request, can be chosen in
various ways, e.g., as described above. Requests of these
types may also origin from the equipment attached to the

30   node. It is possible to, e.g., manually initiate the re-
allocation and decide how many slots that are to be re-
allocated. Also, the allocation of slots may be control-
led by a network controller controlling the allocation of
slots to one or more nodes, such as a master node con-

35   trolling the allocation of slots to a slave node. How-
ever, resilience has to be implemented in order to avoid
oscillation and thus overhead for control signalling.

The procedures and mechanisms according to the invention are simple and easily implemented. The performance of the time multiplexed network is strongly improved and the fragmentation is maintained low. Also, the

5   reallocation of a slot to a new home node may be realised even though the slot is in use.

As is understood by those skilled in the art, different variations and modifications of the invention may be made without departing from the scope of the

10   invention, which is defined by the accompanying claims.

CLAIMS

1. A method for allocating access to time slots used
for transferring data between nodes in a time multiplexed
network, whose bandwidth is divided into cycles which in
turn are divided into time slots, wherein a slot alloca-
ted to a primary home node may be temporarily allocated
to a temporary home node and subsequently reallocated to
the primary home node, said temporary home node instead
of said primary home node then temporarily having the
write access to said slot, said method comprising the
steps of:
    evaluating the degree of temporary allocation of
slots, and
    altering, based upon said evaluation, the allocation
of slots to primary home nodes in order to decrease the
need for temporary allocation of slots within said
network.

2. A method as claimed in claim 1, wherein said
slots comprises control slots control slots for control
signalling and data slots for transferring data.

3. A method as claimed in claim 1 or 2, wherein said
evaluating and altering steps comprises:
    evaluating the degree of temporary allocation of
slots to a first node, and
    increasing, based upon said evaluation, the number
of slots having said first node as primary home node in
response thereto in order to decrease the need for tempo-
rary allocation of slots within said network.

4. A method as claimed in claim 1, 2 or 3, wherein
said altering step comprises:
    said first node sending a request to a second node,
requesting the allocation of slots to the first node as
primary home node; and

said second node allocating in response thereto, based upon an evaluation of it's own slot demand, slots having the second node as primary home node to said first node as new primary home node, thereby increasing the

5   amount of slots having the first node as primary home node and decreasing the amount of slots having the second node as primary home node.

5. A method as claimed in claim in any one of the

10   preceding claims, wherein said evaluating step is performed by said second node.

6. A method as claimed in claim 1 or 2, wherein said evaluating and slot altering step is performed by a

15   network control unit.

7. A method as claimed in any one of the preceding claims, wherein the step of altering or increasing of the number of slots having the first node as primary home

20   node comprises primarily allocating slots thereto that are contiguous with other slots already having the first node as primary home node.

8. A method as claimed in any one of the preceding

25   claims, said method being implemented in a Dynamic Synchronous Transfer Mode (DTM) network.

9. A method as claimed in any one of the preceding claims, wherein the slots to be allocated from a second

30   node to the first node as primary home node are contiguous and thus define a slot range.

10. A method as claimed in any one of the preceding claims, wherein the allocating of a number of slots from

35   a second node to the first node comprises:
       designating the second node as present node;

allocating said number of slots from the present
node to a next node being a home node for a neighbouring
slot or slot range; and
        designating said next node as the present node and
5   repeating the step of allocating said number of slots
from the present node to a next node until said number of
slots have been allocated to the first node.

        11. A method as claimed in claim 10, wherein the
10 number of slots between the slot or slot range of the
next node and the slot or slot range of the first node is
smaller than the number of slots between the slot or slot
range of the present node and the slot or slot range of
the first node.
15

        12. A method as claimed in any one of the preceding
claims, comprising the step of, at least during network
start-up, assigning a contiguous slot range to a first
node as primary home node and assigning another,
20 preferably following, contiguous slot range to a next
node as primary home node and so on, wherein the number
of slot ranges preferably equals the number of nodes.

        13. A method as claimed in claim 12, further compri-
25 sing:
        informing each node about upper and lower bounds of
the slot range having the respective node as primary home
node;
        comparing in a node the slot number of a slot with
30 the upper and lower bounds of the slot range having the
node as primary home node;
        allocating, if said slot number is lower than the
lower bound of the slot range having said node as primary
home node, the slot to a next node having a neighbouring
35 lower slot range;
        allocating, if said slot number is higher than the
upper bound of the slot range having said node as primary

home node, the slot to a next node having a neighbouring higher slot range.

14. A method as claimed in any one of the preceding
5   claims, wherein said altering step is performed, as a result of said evaluating step, when a node has temporarily borrowed slots from other nodes a significant number of times.

10   15. A method as claimed in any one of the preceding claims, wherein said altering step is performed, as a result of said evaluating step, when the quotient of temporarily borrowed slot capacity of a node as temporary home node and the slot capacity assigned to said node as
15   primary home node exceeds a predetermined value.

16. A method as claimed in any one of the preceding claims, wherein a first node sends a request to a second node, requesting the allocation of slots to the first
20   node as primary home node, comprising selecting the second node as the node that has most free slot capacity.

17. A method as claimed in any one of the preceding claims, wherein a first node sends a request to a second
25   node, requesting the allocation of slots to the first node as primary home node, wherein said second node is derived form a status table, which is maintained, preferably in each node, with information about the free capacity in respective node.
30

18. A method as claimed in any one of the preceding claims, wherein a first node sends a request to a second node, requesting the allocation of slots to the first node as primary home node, wherein the second node is
35   selected as the node from which, during a predetermined period, the first node has requested or temporarily borrowed most slot capacity.

19. A method as claimed in any one of the preceding claims, wherein a first node sends a request to a second node, requesting the allocation of slots to the first node as primary home node, wherein said second node is derived from a record that is maintained, preferably in each node, with information about its requested or temporarily borrowed slot capacity during a predetermined period.

20. A method as claimed in any one of the preceding claims, further comprising, when a node requests a temporary allocation of slots to it as temporary home node, allocating a fraction, or at least one, of said slots to said node as primary home node and remaining slots to said node as temporary home node.

21. A method as claimed in any one of the preceding claims, wherein slots being allocated a first node as primary home node only refers to one or more predetermined segments of the network, thereby allowing the same slots to be allocated to other nodes on other segments.

22. A method for allocating access to time slots used for transferring data between nodes in a time multiplexed network, whose bandwidth is divided into cycles which in turn are divided into control slots for control signalling and data slots for transferring data, wherein a first node has write access to at least a first slot or slot range, comprising the steps of
determining an increased demand for transferring capacity in the first node;
allocating an extra slot or slot range to the first node in such a way that said extra slot or slot range are contiguous with said first slot or slot range as a result of said increased demand.

23. A method as claimed in claim 21, wherein the allocating of a number of slots in a slot or slot range from a second node to the first node comprises:

designating the second node as present node;

5   allocating said number of slots from the present node to a next node having access to a neighbouring slot or slot range; and

designating said next node as the present node and repeating the step of allocating said number of slots

10   from the present node to a next node until said number of slots have been allocated to the first node.

24. A method as claimed in claim 22, wherein the number of slots between the slot or slot range of the

15   next node and the slot or slot range of the first node is smaller than the number of slots between the slot or slot range of the present node and the slot or slot range of the first node.

20   25. A controller in a time multiplexed network, whose bandwidth is divided into cycles which in turn are divided into time slots, wherein slots allocated to a primary home node may be temporarily allocated to a temporary home node, said temporary home node instead of

25   said primary home node then temporarily having the write access to said slots, and subsequently reallocated to said primary home node, said controller comprising:

means for evaluating the degree of temporary allocation of slots to a first node, and

30   means for changing, based upon said evaluation, the number of slots having said first node as primary home node in response thereto in order to decrease the need for temporary allocation of slots within said network.

35   26. A controller as claimed in claim 25, wherein said slot comprises control slots for control signalling and data slots for transferring data.

27. A controller as claimed in claim 25 or 26, further comprising means for sending a request to a second node, requesting the allocation of slots to the first node as primary home node.

28. A controller as claimed in claim 25, 26 or 27, wherein said controller is arranged to primarily allocate slots to the first node that are contiguous with other slots already having the first node as primary home node.

29. A controller as claimed in claim 25, 26, 27 or 28, wherein said controller is provided as a node controller in said first node.

30. A controller as claimed in anyh one of claims 25-29, wherein said network is a Dynamic Synchronous Transfer Mode (DTM) network.

31. A system implemented in a time multiplexed network, whose bandwidth is divided into cycles which in turn are divided into time slots, wherein slots allocated to a primary home node may be temporarily allocated to a temporary home node, said temporary home node instead of said primary home node then temporarily having the write access to said slots, and subsequently reallocated to said primary home node, said system comprising:
    means for evaluating the degree of temporary allocation of slots, and
    means for changing, based upon said evaluation, the allocation of slots to different nodes as primary home nodes in response thereto in order to decrease the need for temporary allocation of slots within said network.

32. A system as claimed in claim 31, wherein each cycle are divided control slots for control signalling and data slots for transferring data.

33. A system as claimed in claim 31 or 32, further comprising:
        means for sending a request to a second node,
5   requesting the allocation of slots to the first node as primary home node; and
        means for allocating, based upon an evaluation of the second nodes own slot demand, slots having the second node as primary home node to said first node as new
10 primary home node, thereby increasing the amount of slots having the first node as primary home node and decreasing the amount of slots having the second node as primary home node.

15   34. A system as claimed in claim 31, 32 or 33, wherein said system is arranged to primarily allocate slots to the first node that are contiguous with other slots already having the first node as primary home node.

20   35. System as claimed in claim 31, 32 33 or 34, wherein a number of slots in a slot or slot range are allocated from a second node to the first node as home node, further comprising:
        means for designating the second node as present
25 node;
        means for allocating said number of slots from the present node to a next node having access to a neighbouring slot or slot range; and
        means for designating said next node as the present
30 node and repeating the step of allocating said number of slots from the present node to a next node until said number of slots have been allocated to the first node.
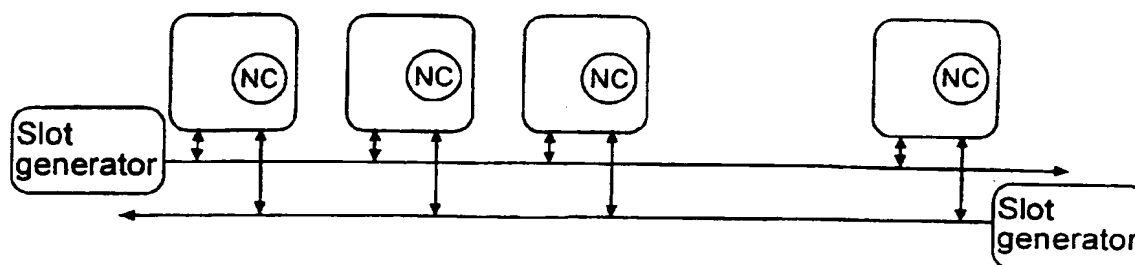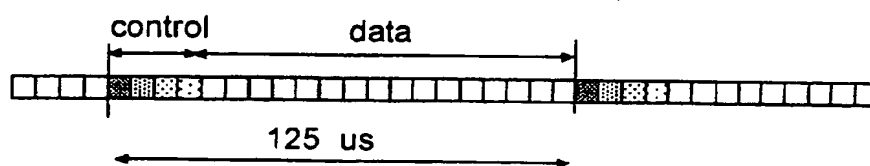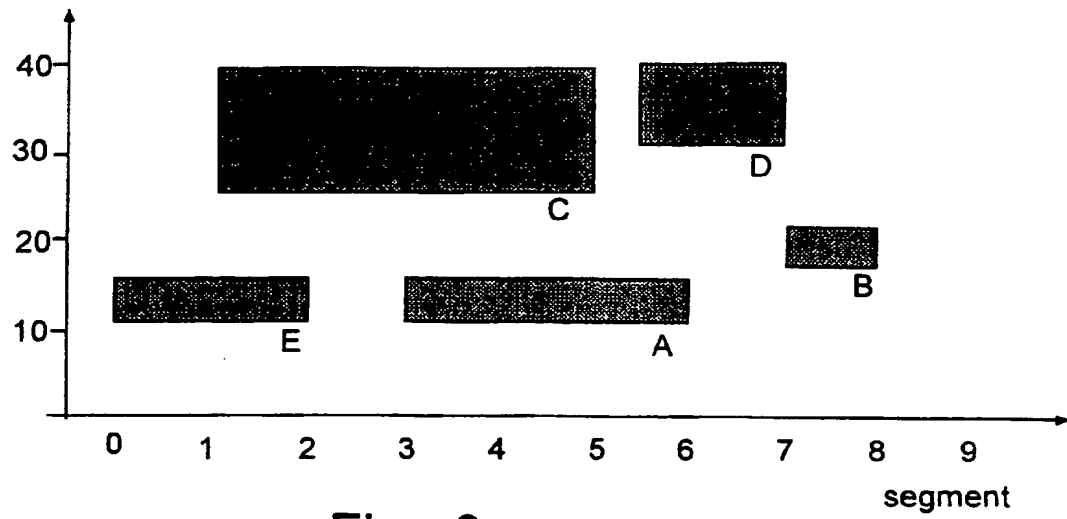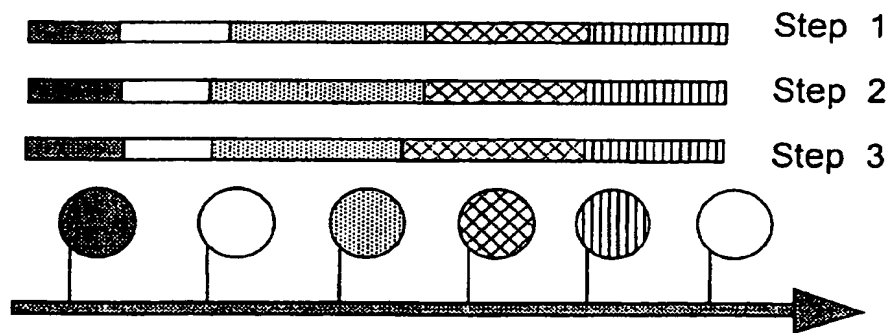
Fig. 1

Fig. 2

Fig. 3

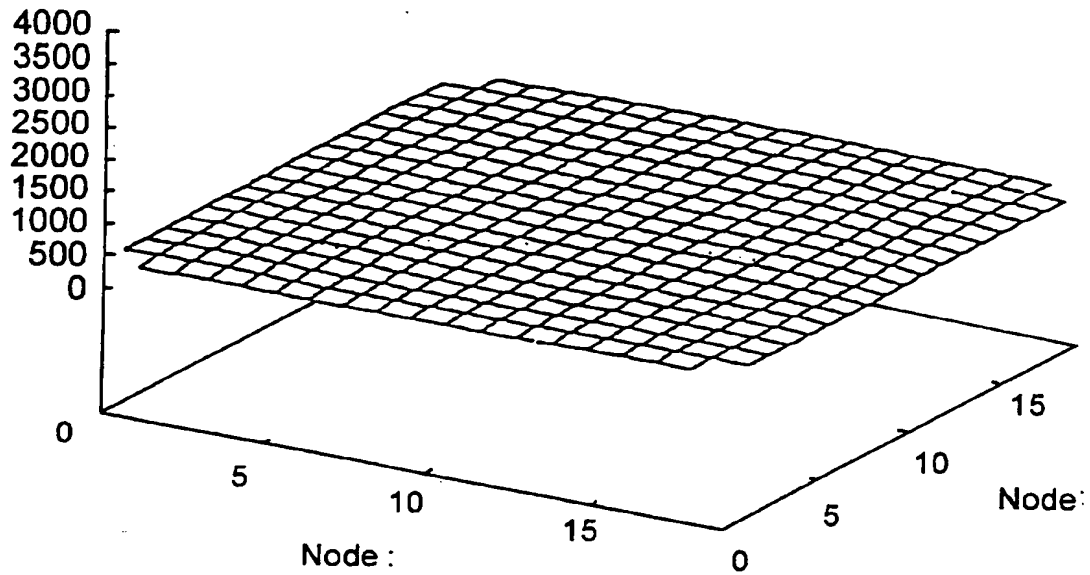Step 1

Step 2

Step 3

Fig . 4

Number of blocks assigned as home

Fig. 5

Number of blocks assigned
as home

Fig. 6
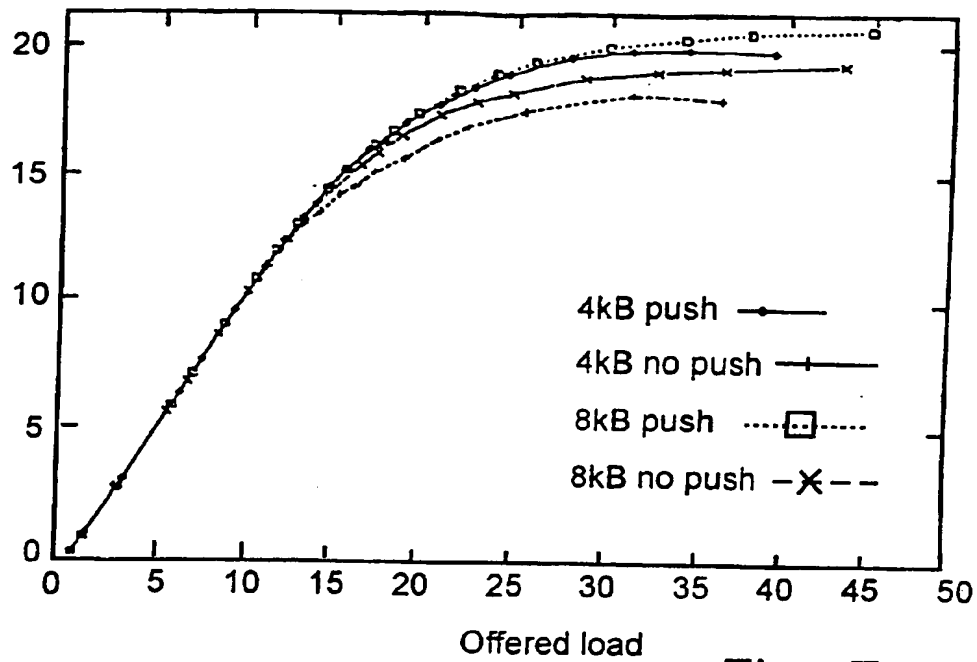
Fig. 7
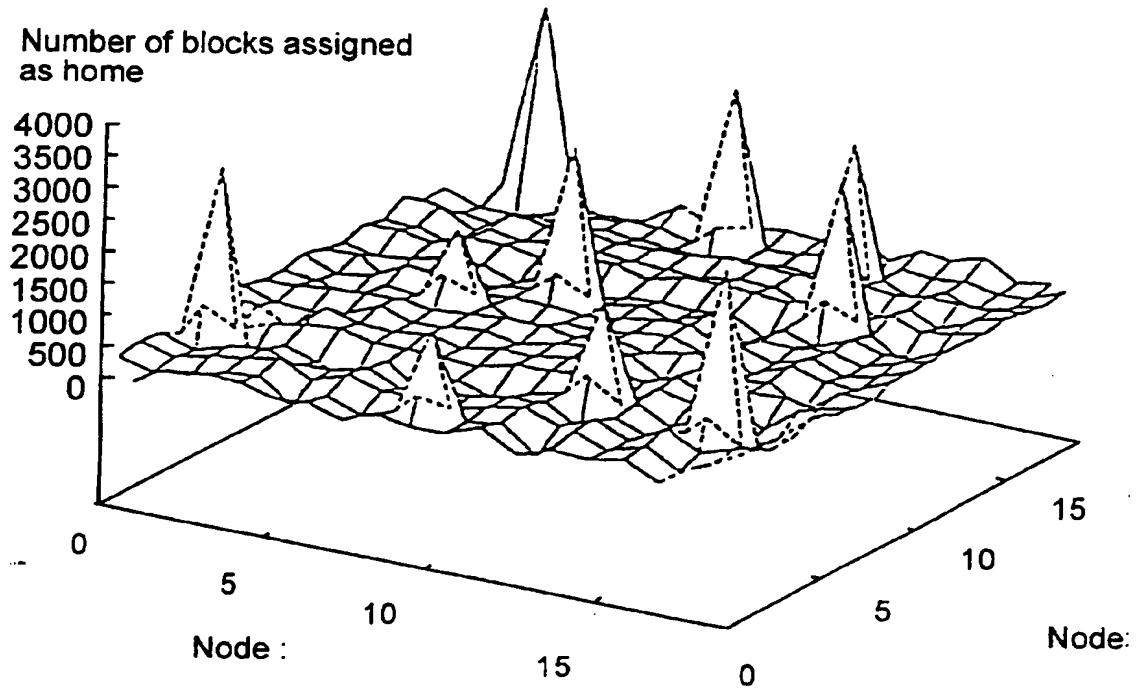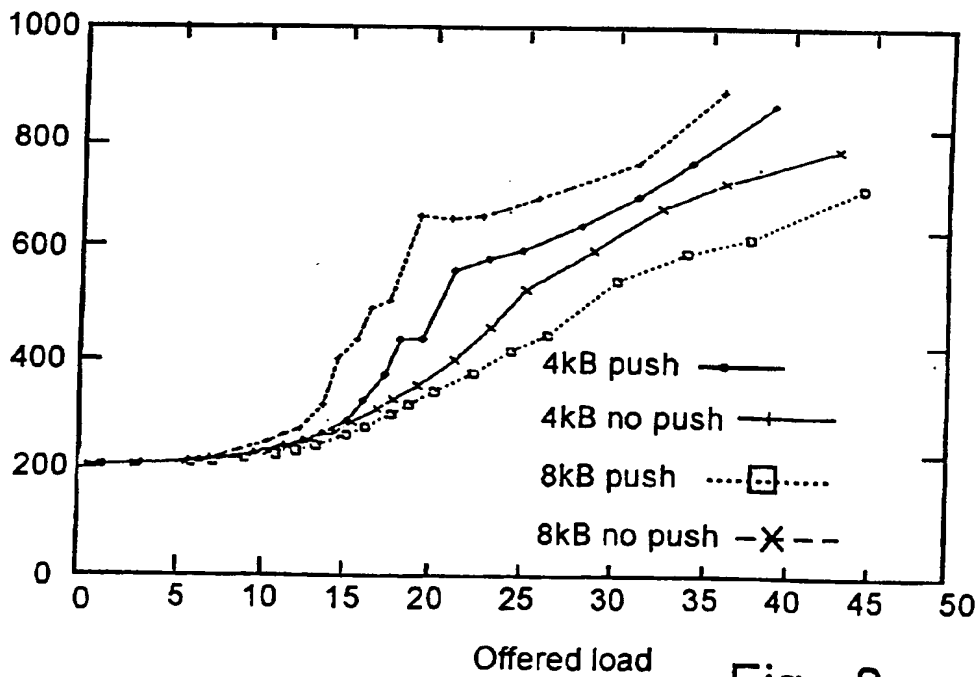
Channel set-up time (microseconds)

Fig. 8

INTERNATIONAL SEARCH REPORT

	International application No. PCT/SE 97/00520

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04L 12/43, H04L 12/64
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04L, H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	IEEE Journal on Selected Areas in Communications, Volume 14, No 2, February 1996, Bohm C. et al, "Fast Circuit Switching for the Next Generation of High Performance Networks" page 298 - page 305	1,2,4-8,10, 12,20,22, 25-35
	--	
X	Patent Abstracts of Japan, Vol 17,No 150, E-1339, abstract of JP,A,4-316240 (FUJI XEROX CO LTD.), 6 November 1992 (06.11.92)	1
	--	
A	EP 0477659 A1 (ALCATEL FACE S.P.A.), 1 April 1992 (01.04.92), column 6, line 11 - line 34	1-35
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[X] Further documents are listed in the continuation of Box C.	[X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 July 1997	12.07.97
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Friedrich Kühn Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 97/00520

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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P,A	EP 0726661 A2 (NEC CORPORATION), 14 August 1996 (14.08.96), abstract -- ---------	1-35

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		ES 2083497 T	16/04/96
		IT 220082 Z	09/06/93
		IT 1243085 B	23/05/94
		JP 4264845 A	21/09/92
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		DE 69030534 D	00/00/00
		EP 0407367 A,B	09/01/91
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EP 0726661 A2	14/08/96	JP 8204673 A	09/08/96